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Frett et al.

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(54) **SYSTEMS AND METHODS TO IMPROVE TIMESTAMP TRANSITION RESOLUTION**

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This patent is subject to a terminal disclaimer.

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(Continued)

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G10L 19/018 (2013.01)

(Continued)

(52) **U.S. Cl.**

CPC ***G10L 19/018*** (2013.01); ***G10L 25/45*** (2013.01); ***H04N 21/4302*** (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC H04N 21/8547; H04N 21/4302; H04N 21/8358; H04N 19/467; G10L 25/45; G10L 19/018

(Continued)

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(57) **ABSTRACT**

Example apparatus to improve timestamp transition resolution of watermarks are disclosed. A disclosed example apparatus is to decode timestamps in respective ones of detected watermarks, estimate a first transition window indicative of a transition between a first time period to a second time period based on a first one of the timestamps and a second one of the timestamps, and when the first transition window does not satisfy a threshold, estimate a second transition window indicative of a transition between the second time period and a third time period based on the second one of the timestamps and a third one of the timestamps. The disclosed example apparatus is also to

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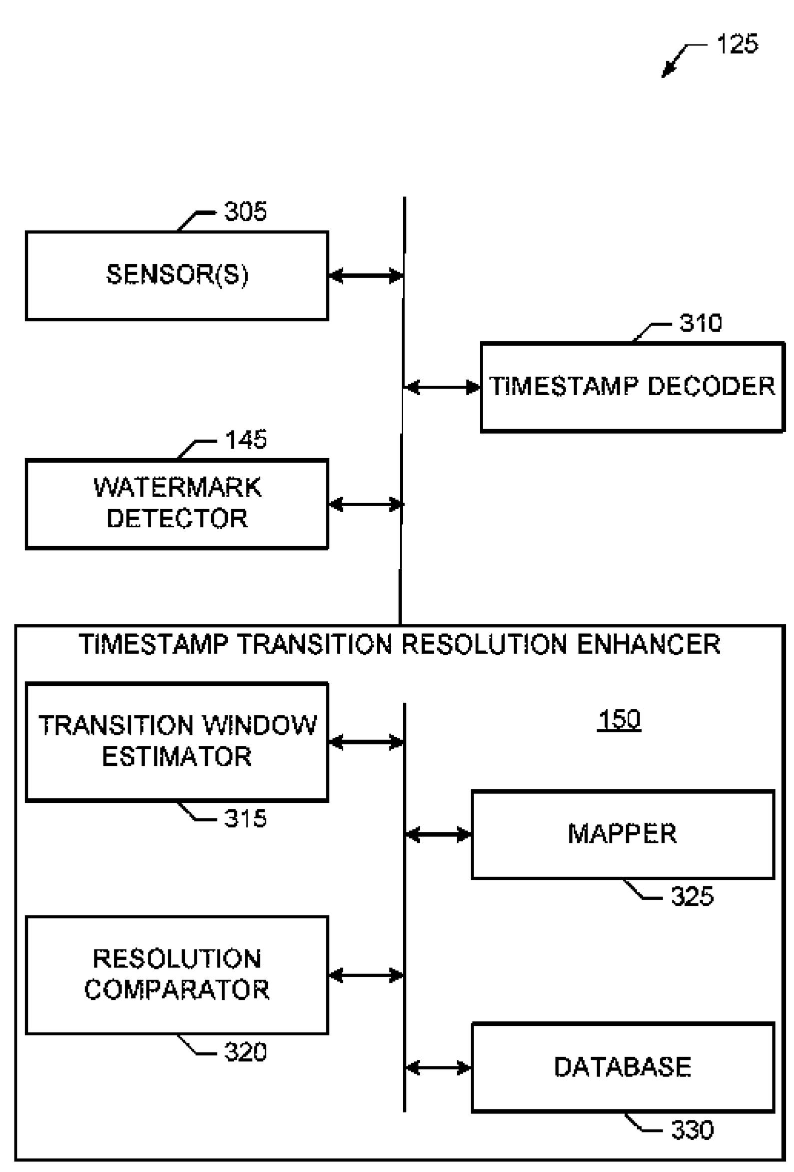

determine a first mapped transition window based on an intersection of the first transition window and the second transition window, and set the first mapped transition window as a reference time transition window for subsequent time periods.

21 Claims, 6 Drawing Sheets

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(58) **Field of Classification Search**
USPC 700/94
See application file for complete search history.

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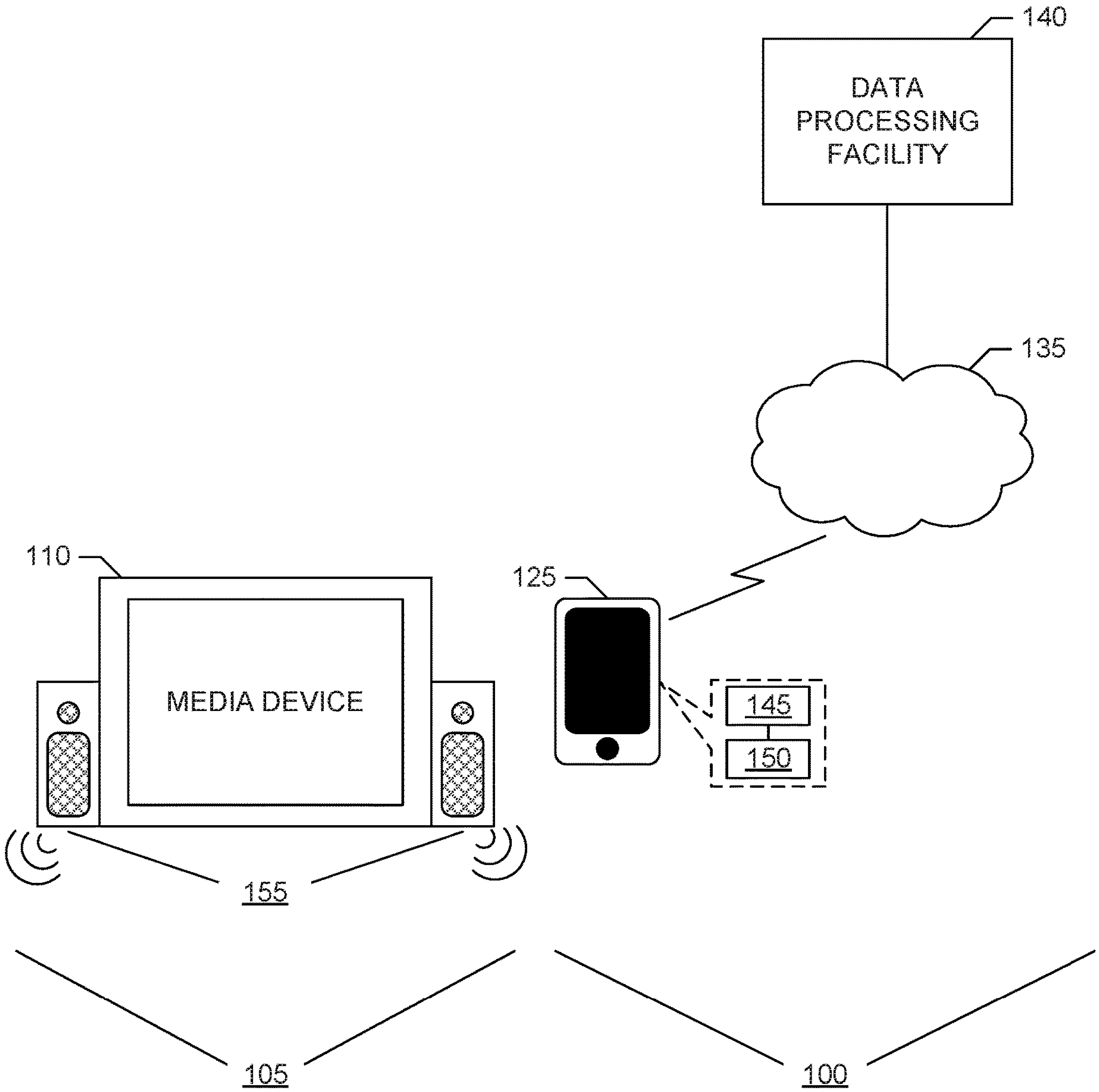
140
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135
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MEDIA DEVICE
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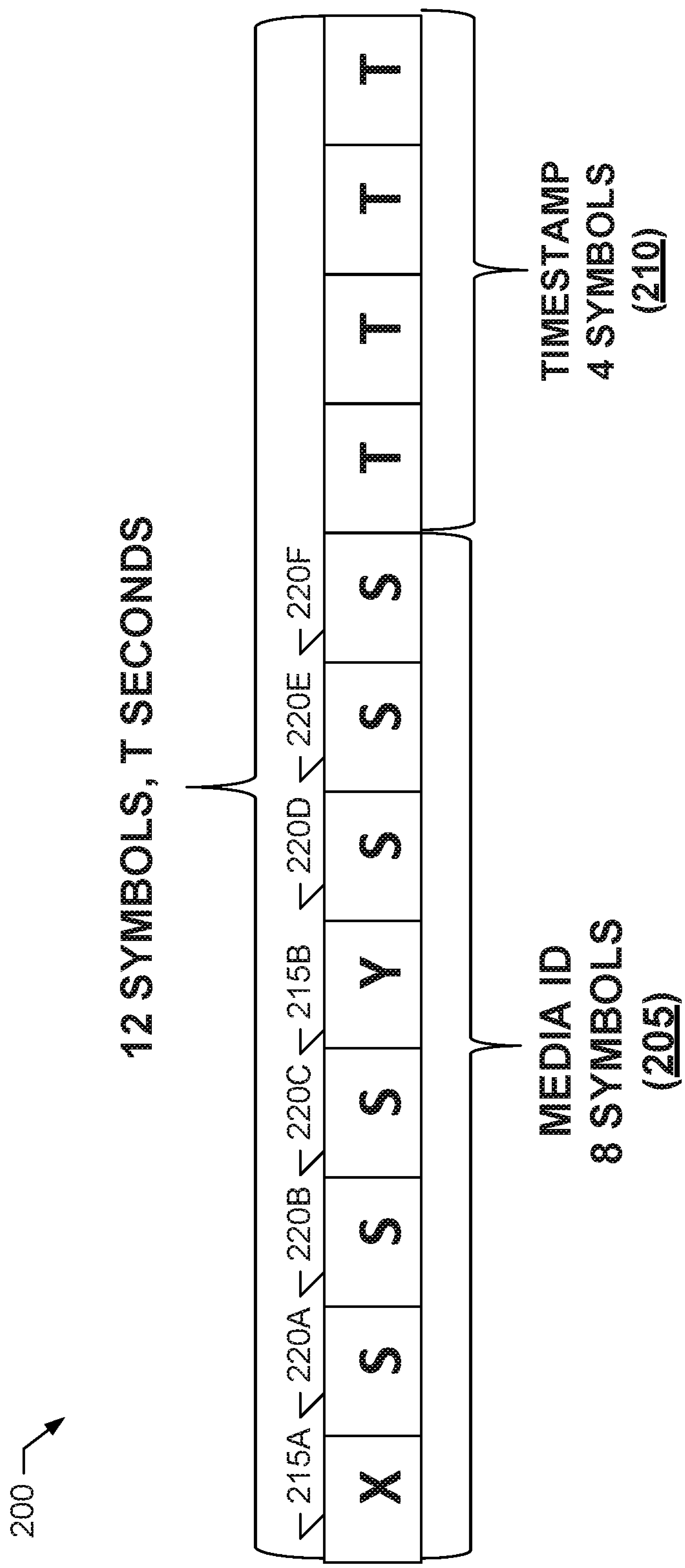
FIG. 1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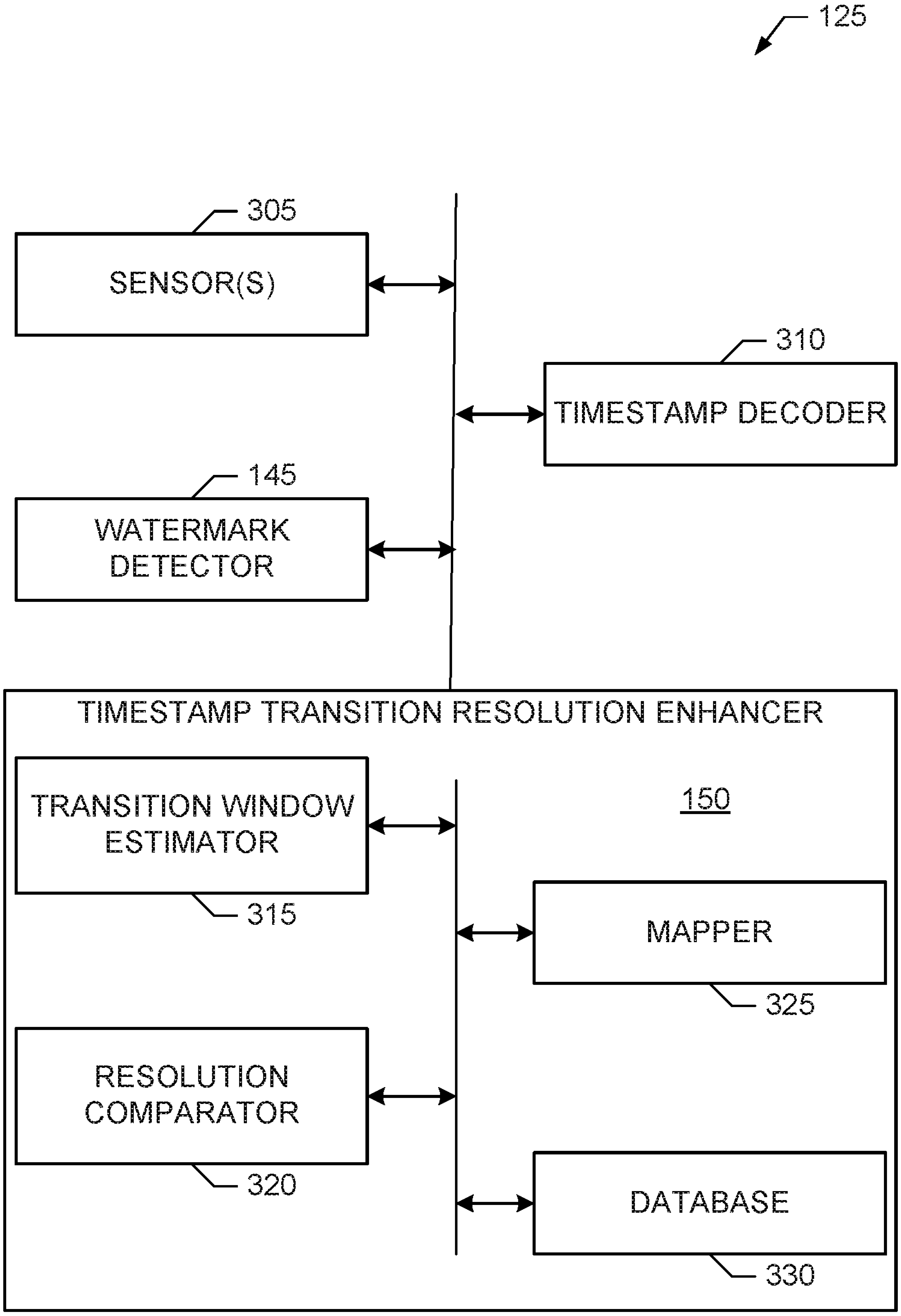
MEDIA ID
8 SYMBOLS
(205)
TIMESTAMP
4 SYMBOLS
(210)

FIG. 2



125
305
SENSOR(S)
310
TIMESTAMP DECODER
145
WATERMARK DETECTOR
TIMESTAMP TRANSITION RESOLUTION ENHANCER
TRANSITION WINDOW ESTIMATOR
315
150
MAPPER
325
RESOLUTION COMPARATOR
320
DATABASE
330

FIG. 3

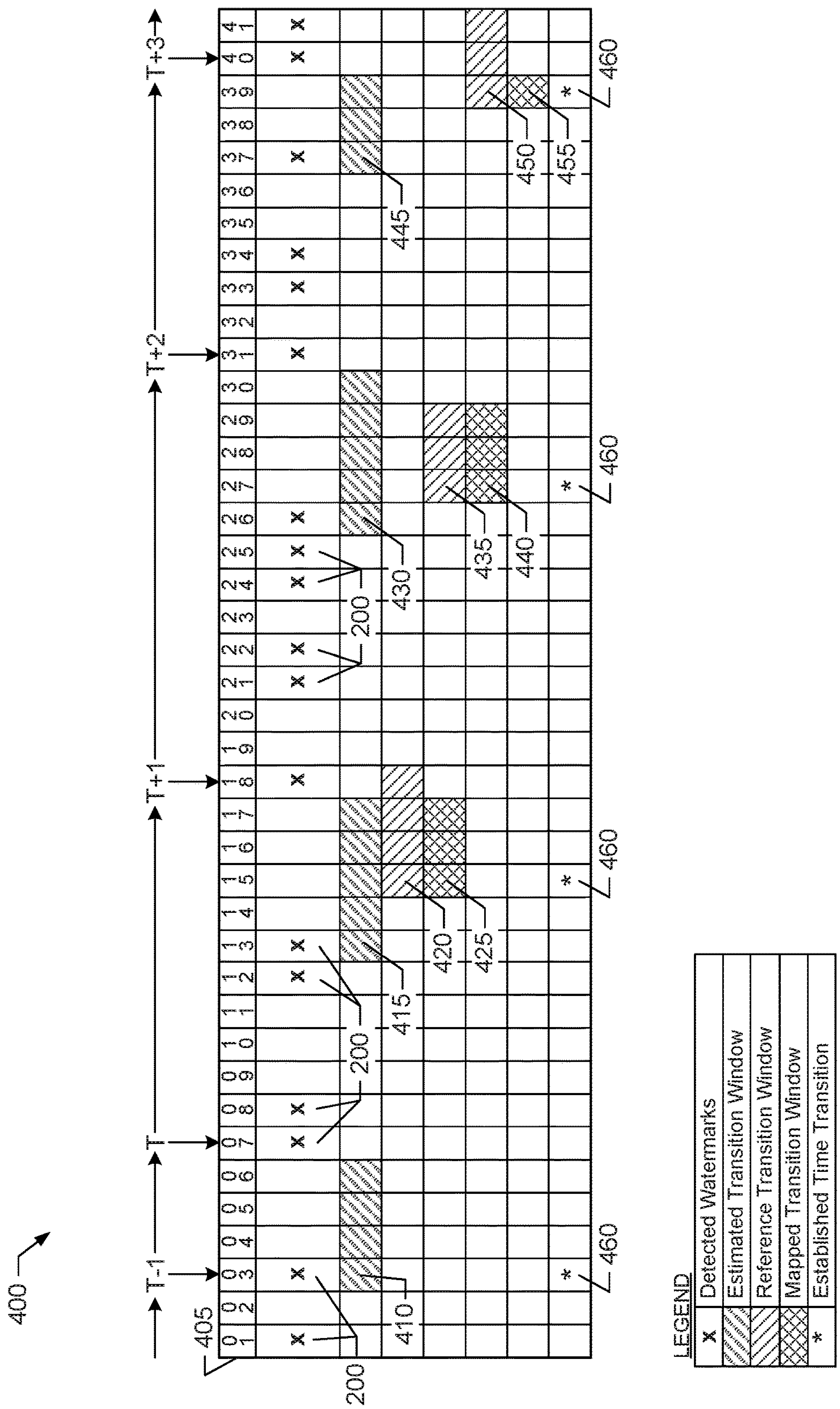

400
405
T-1
T
T+1
T+2
T+3
200
410
415
420
425
430
435
440
445
450
455
460
LEGEND
Detected Watermarks
Estimated Transition Window
Reference Transition Window
Mapped Transition Window
Established Time Transition

FIG. 4

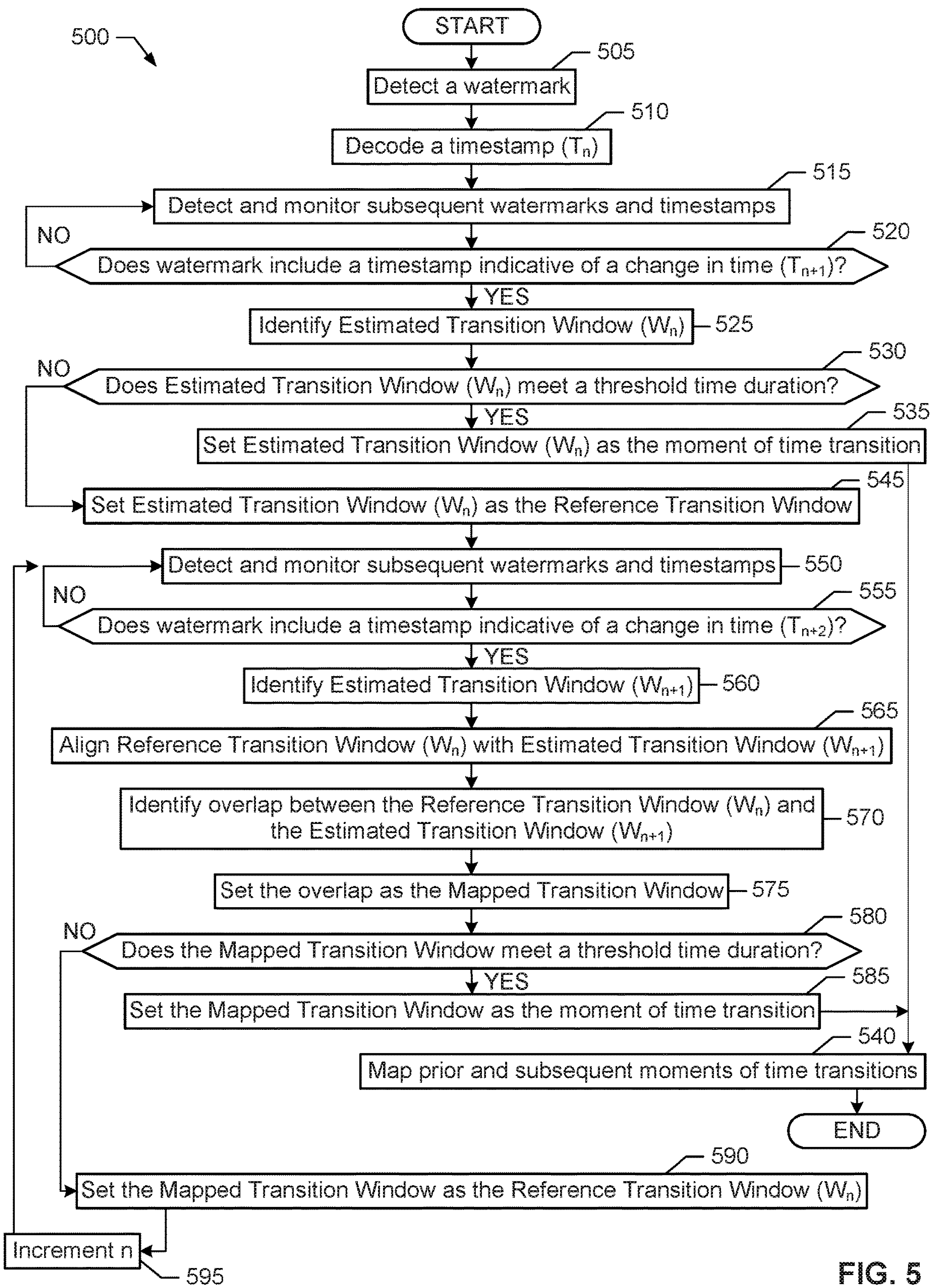

500
START
Detect a watermark
505
Decode a timestamp (T_n)
510
Detect and monitor subsequent watermarks and timestamps
515
NO
Does watermark include a timestamp indicative of a change in time (T_{n+1})?
520
YES
Identify Estimated Transition Window (W_n)
525
NO
Does Estimated Transition Window (W_n) meet a threshold time duration?
530
YES
Set Estimated Transition Window (W_n) as the moment of time transition
535
Set Estimated Transition Window (W_n) as the Reference Transition Window
545
Detect and monitor subsequent watermarks and timestamps
550
NO
Does watermark include a timestamp indicative of a change in time (T_{n+2})?
555
YES
Identify Estimated Transition Window (W_{n+1})
560
Align Reference Transition Window (W_n) with Estimated Transition Window (W_{n+1})
565
Identify overlap between the Reference Transition Window (W_n) and the Estimated Transition Window (W_{n+1})
570
Set the overlap as the Mapped Transition Window
575
NO
Does the Mapped Transition Window meet a threshold time duration?
580
YES
Set the Mapped Transition Window as the moment of time transition
585
Map prior and subsequent moments of time transitions
540
END
Set the Mapped Transition Window as the Reference Transition Window (W_n)
590
Increment n
595

FIG. 5

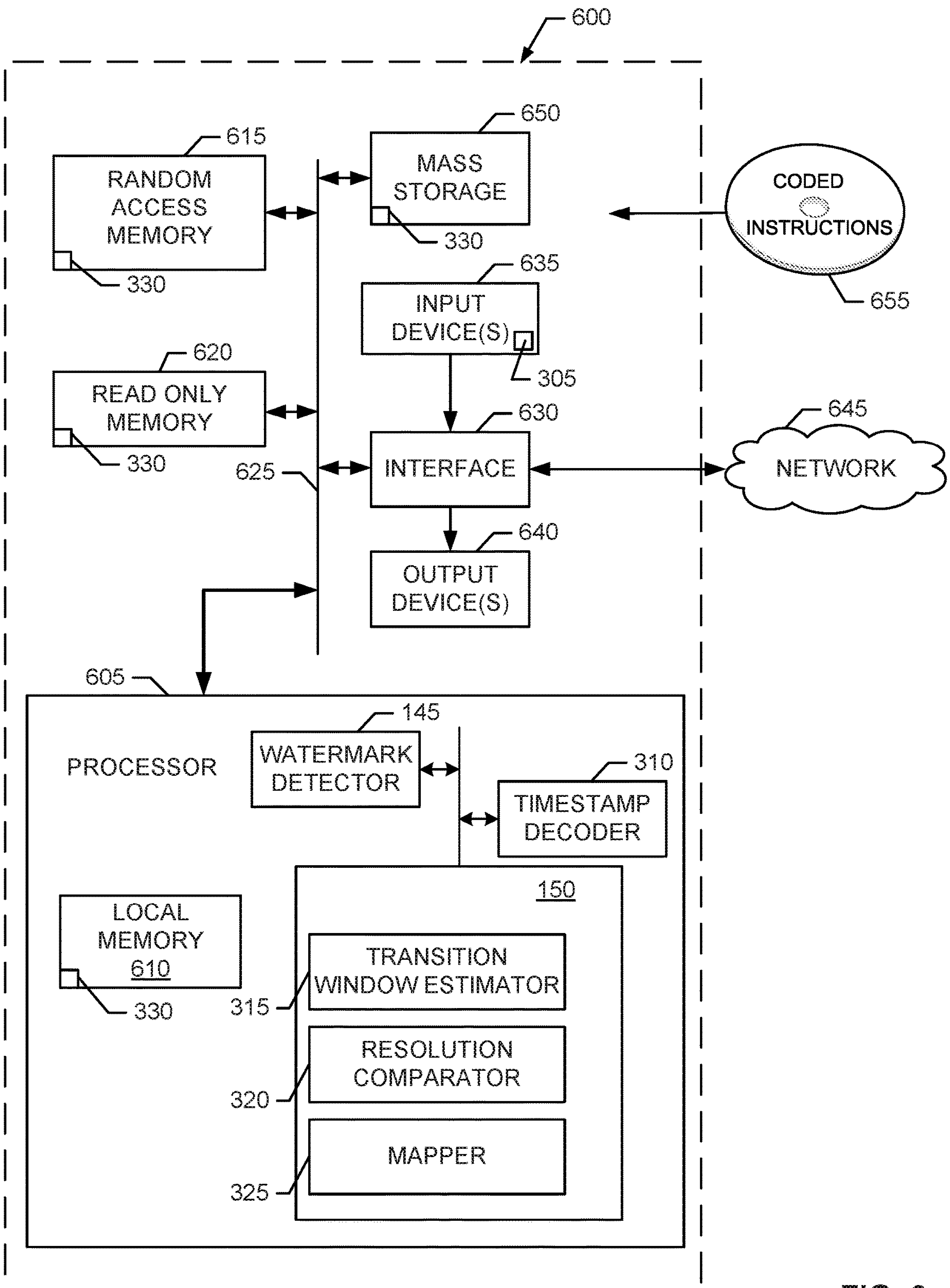

600
615
RANDOM ACCESS MEMORY
330
650
MASS STORAGE
330
CODED INSTRUCTIONS
655
635
INPUT DEVICE(S)
305
620
READ ONLY MEMORY
330
625
630
INTERFACE
645
NETWORK
640
OUTPUT DEVICE(S)
605
PROCESSOR
145
WATERMARK DETECTOR
310
TIMESTAMP DECODER
150
LOCAL MEMORY 610
330
315
TRANSITION WINDOW ESTIMATOR
320
RESOLUTION COMPARATOR
325
MAPPER

FIG. 6

SYSTEMS AND METHODS TO IMPROVE TIMESTAMP TRANSITION RESOLUTION

RELATED APPLICATIONS

This patent arises from a continuation of U.S. patent application Ser. No. 16/943,715, titled "SYSTEMS AND METHODS TO IMPROVE TIMESTAMP TRANSITION RESOLUTION," filed Jul. 30, 2020, which is a continuation of U.S. patent application Ser. No. 16/450,057, titled "SYSTEMS AND METHODS TO IMPROVE TIMESTAMP TRANSITION RESOLUTION," filed Jun. 24, 2019, which is a continuation of U.S. patent application Ser. No. 15/800,466, titled "SYSTEMS AND METHODS TO IMPROVE TIMESTAMP TRANSITION RESOLUTION," filed Nov. 1, 2017, which claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application No. 62/573,798, which was filed on Oct. 18, 2017. Priority to U.S. patent application Ser. No. 16/943,715, U.S. patent application Ser. No. 16/450,057, U.S. patent application Ser. No. 15/800,466, and U.S. Provisional Patent Application No. 62/573,798 is claimed. U.S. patent application Ser. No. 16/943,715, U.S. patent application Ser. No. 16/450,057, U.S. patent application Ser. No. 15/800,466, and U.S. Provisional Patent Application No. 62/573,798 are hereby incorporated herein by reference in their entireties.

FIELD OF THE DISCLOSURE

This disclosure relates generally to media watermarking, and, more particularly, to systems and methods to improve timestamp transition resolution.

BACKGROUND

Watermarks can be embedded or otherwise included in media to enable additional information to be conveyed with the media. For example, audio watermarks can be embedded or otherwise included in the audio data/signal portion of a media stream, file and/or signal to convey data, such as media identification information, copyright protection information, timestamps indicative of broadcast time, etc., with the media. Such watermarks enable monitoring of the distribution and/or use of media, such as by detecting watermarks present in television broadcasts, radio broadcasts, streamed multimedia, etc., to identify the particular media being presented to viewers, listeners, users, etc. Such information can be valuable to advertisers, content providers, and the like.

Prior media monitoring systems employing watermarks typically include watermark decoders that identify the information contained in the watermarks. Some prior systems identify the timestamps in the watermarks and transitions between timestamps to a relatively coarse resolution, such as a resolution of one minute.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an example media monitoring system, which includes an example timestamp transition resolution enhancer constructed in accordance with the teachings of this disclosure.

FIG. **2** illustrates an example watermark to be detected by the example media device monitor of FIG. **1**.

FIG. **3** a block diagram illustrating an example implementation of the timestamp transition resolution enhancer of FIG. **1**.

FIG. **4** illustrates an example mapping of detected watermarks, timestamps, and timestamp transition resolution enhancement performed in accordance with the teachings of this disclosure.

FIG. **5** is a flowchart representative of first example machine readable instructions that may be executed to implement the example media monitoring system of FIG. **1** and/or the example timestamp transition resolution enhancer of FIG. **3**.

FIG. **6** is a block diagram of an example processor platform structured to execute the example machine readable instructions of FIG. **5** to implement the example media monitoring system of FIG. **1** and/or the example timestamp transition resolution enhancer of FIG. **3**.

The figures are not to scale. Wherever possible, the same reference numbers will be used throughout the drawing(s) and accompanying written description to refer to the same or like parts.

DETAILED DESCRIPTION

Systems, methods, apparatus, and articles of manufacture (e.g., non-transitory, physical storage media) to improve timestamp transition resolution in watermarks are disclosed herein. Example watermark timestamp transition resolution enhancing systems include a watermark detector to detect watermarks and a decoder to decode timestamps in respective ones of the watermarks. Some such example systems also include a timestamp transition resolution enhancer to estimate a first transition window indicative of a transition between a first time period to a second time period based on a first one of the timestamps and a second one of the timestamps. In some examples, the timestamp transition resolution enhancer also estimates, when the first transition window does not satisfy a threshold, a second transition window indicative of a transition between the second time period and a third time period based on the second timestamp and a third one of the timestamps. In addition, the example timestamp transition resolution enhancer of some examples determines a first mapped transition window based on an intersection of the first transition window and the second transition window and sets the first mapped transition window as a reference time transition window for subsequent time periods.

In some examples, the timestamp transition resolution enhancer is to set the first transition window as an established time transition when the first transition window satisfies the threshold.

In some examples, the timestamp transition resolution enhancer is to set the first mapped transition window as an established time transition when the first mapped transition window satisfies the threshold.

In some examples, the timestamp transition resolution enhancer is to estimate, when the first mapped transition window does not satisfy the threshold, a third transition window indicative of a transition between the third time period and a fourth time period of time based on the third timestamp and a fourth one of the timestamps. In such examples, the timestamp transition resolution enhancer also is to determine a second mapped transition window based on an intersection of the first mapped transition window and the third transition window and set the second mapped transition window as the reference time transition window.

In some examples, the timestamp transition resolution enhancer is to set the second mapped transition window as an established time transition when the second mapped transition window satisfies the threshold.

In some examples, the timestamp transition resolution enhancer is to set an established time transition based on at least one of the first transition window or the first mapped transition window satisfying the threshold. In such examples, the timestamp transition resolution enhancer also is to retroactively map time transitions in the media signal based on the established time transition.

In some examples, respective ones of the time periods have minute durations and the threshold is about five seconds.

In some examples, the first transition window is identified when a first timestamp in a first watermark is different than a second timestamp in a second watermark.

Also disclosed herein are example methods that include estimating, by executing an instruction with a processor, a first transition window indicative of a transition between a first time period to a second time period based on a first timestamp of a first watermark and a second timestamp of a second watermark. Some such example methods also include estimating, by executing an instruction with a processor when the first transition window does not satisfy a threshold, a second transition window indicative of a transition between the second time period and a third time period based on the second timestamp and a third timestamp. In addition, some example methods include determining, by executing an instruction with a processor, a first mapped transition window based on an intersection of the first transition window and the second transition window and setting the first mapped transition window as the reference time transition window for subsequent time periods.

Some example methods also include setting, by executing an instruction with a processor, the first transition window as an established time transition when the first transition window satisfies the threshold.

Some example methods also include setting, by executing an instruction with a processor, the first mapped transition window as an established time transition when the first mapped transition window satisfies the threshold.

Some example methods also include estimating, by executing an instruction with a processor when the first mapped transition window does not satisfy the threshold, a third transition window indicative of a transition between the third time period and a fourth time period of time based on the third timestamp and a fourth timestamp. Such example methods also include determining, by executing an instruction with a processor, a second mapped transition window based on an intersection of the first mapped transition window and the third transition window and setting the second mapped transition window as the reference time transition window.

Some example methods include setting, by executing an instruction with a processor, the second mapped transition window as an established time transition when the second mapped transition window satisfies the threshold.

Some example methods include setting, by executing an instruction with a processor, an established time transition based on at least one of the first transition window or the first mapped transition window satisfying the threshold. Such example methods also include retroactively mapping, by executing an instruction with a processor, time transitions in the media signal based on the established time transition.

Some example methods also include respective ones of the time periods have minute durations and the threshold is about five seconds.

Some example methods also include comparing, by executing an instruction with a processor, a first timestamp in a first watermark and a second time stamp in a second watermark and identifying, by executing an instruction with a processor, the first transition window when the first timestamp and the second timestamp are different.

Also disclosed herein are non-transitory machine-readable storage media comprising machine-readable instructions which, when executed, cause a machine to at least: estimate a first transition window indicative of a transition between a first time period to a second time period based on a first timestamp of a first watermark and a second timestamp of a second watermark. The example instructions of some such examples also cause the machine to estimate, when the first transition window does not satisfy a threshold, a second transition window indicative of a transition between the second time period and a third time period based on the second timestamp and a third timestamp. In addition, the example instructions of some such examples cause the machine to determine a first mapped transition window based on an intersection of the first transition window and the second transition window and set the first mapped transition window as the reference time transition window for subsequent time periods.

In some examples, the instructions cause the machine to set the first transition window as an established time transition when the first transition window satisfies the threshold.

In some examples, the instructions further cause the machine to set the first mapped transition window as an established time transition when the first mapped transition window satisfies the threshold.

In some examples, the instructions further cause the machine to estimate, when the first mapped transition window does not satisfy the threshold, a third transition window indicative of a transition between the third time period and a fourth time period of time based on the third timestamp and a fourth timestamp. In such examples, the instructions also cause the machine to determine a second mapped transition window based on an intersection of the first mapped transition window and the third transition window and set the second mapped transition window as the reference time transition window.

In some examples, the instructions further cause the machine to set the second mapped transition window as an established time transition when the second mapped transition window satisfies the threshold.

In some examples, the instructions further cause the machine to set an established time transition based on at least one of the first transition window or the first mapped transition window satisfying the threshold and retroactively map time transitions in the media signal based on the established time transition.

In some examples, respective ones of the time periods have minute durations and the threshold is about five seconds.

In some examples, the instructions further cause the machine to identify the first transition window when a first timestamp in a first watermark is different than a second timestamp in a second watermark.

Also disclosed herein are example systems that include means for detecting watermarks and means for decoding timestamps in respective ones of the watermarks. Such example systems also includes means for estimating transition windows by estimating a first transition window indicative of a transition between a first time period to a second time period based on a first one of the timestamps and a second one of the timestamps, and estimating, when the first transition window does not satisfy a threshold, a second transition window indicative of a transition between the second time period and a third time period based on the second timestamp and a third one of the timestamps. Such example systems also include means for determining a first mapped transition window based on an intersection of the first transition window and the second transition window. In addition, such example systems include means for setting the first mapped transition window as a reference time transition window for subsequent time periods.

In some example systems, the means for setting is to set the first transition window as an established time transition when the first transition window satisfies the threshold.

In some example systems, the means for setting is to set the first mapped transition window as an established time transition when the first mapped transition window satisfies the threshold.

In some example systems, when the first mapped transition window does not satisfy the threshold, the means for estimating is to estimate a third transition window indicative of a transition between the third time period and a fourth time period of time based on the third timestamp and a fourth one of the timestamps. In such example systems, the means for determining is to determine a second mapped transition window based on an intersection of the first mapped transition window and the third transition window. In addition, in such examples, the means for setting is to set the second mapped transition window as the reference time transition window.

In some examples systems, the means for setting is to set the second mapped transition window as an established time transition when the second mapped transition window satisfies the threshold.

In some examples systems, the means for setting is to set an established time transition based on at least one of the first transition window or the first mapped transition window satisfying the threshold. In such example systems, the means for setting also is to retroactively map time transitions in the media signal based on the established time transition.

In some examples systems, respective ones of the time periods have minute durations and the threshold is about five seconds.

In some examples systems, the means for estimating is to identify the first transition window when a first timestamp in a first watermark is different than a second timestamp in a second watermark.

Also disclosed herein are systems that include a watermark detector to detect watermarks and a decoder to decode timestamps in respective ones of the watermarks. Some such example systems include a timestamp transition resolution enhancer to determine moments of transition between time periods of media containing the watermarks based on the timestamps by: (a) estimating a coarse transition window between two time periods; (b) mapping a prior transition window estimate to the estimate of (a); (c) narrowing to a fine transition window estimate based on an overlap between the estimate of (a) and (b); (d) comparing the estimate of (c) to a threshold; (e) repeating (a) through (d) for successive time periods using the fine transition window estimate of (c) as the prior transition window estimate of (b) until the fine transition window estimate of (c) satisfies the threshold; and (e) establishing the fine transition window estimate as an established moment of transition between time periods when the estimate of (c) satisfies the threshold.

In some examples, the timestamp transition resolution enhancer is to identify the moments of transition between time periods of the media signal based on the established moment of transition.

In some examples, the time periods correspond to successive minutes of the media signal and the threshold is about five seconds.

Also disclosed herein are methods that include detecting, by executing an instruction with a processor, watermarks and decoding, by executing an instruction with a processor, timestamps in respective ones of the watermarks. Some such example methods also include determining, by executing an instruction with a processor, moments of transition between time periods of media containing the watermarks based on the timestamps by: (a) estimating a coarse transition window between two time periods; (b) mapping a prior transition window estimate to the estimate of (a); (c) narrowing to a fine transition window estimate based on an overlap between the estimate of (a) and (b); (d) comparing the estimate of (c) to a threshold; (e) repeating (a) through (d) for successive time periods using the fine transition window estimate of (c) as the prior transition window estimate of (b) until the fine transition window estimate of (c) satisfies the threshold; and (**0** establishing the fine transition window estimate as an established moment of transition between windows when the estimate of (c) satisfies the threshold.

In some examples, the method includes identifying, by executing an instruction with a processor, the moments of transition between time periods of the media signal based on the established moment of transition.

In some examples, the method includes the time periods corresponding to successive minutes of the media signal and the threshold is about five seconds.

Also disclosed herein are non-transitory storage media including machine-readable instructions which, when executed, cause a machine to at least detect watermarks and decode timestamps in respective ones of the watermarks. In some examples, the instructions also cause the machine to determine moments of transition between time periods of media containing the watermarks based on the timestamps by: (a) estimating a coarse transition window between two time periods; (b) mapping a prior transition window estimate to the estimate of (a); (c) narrowing to a fine transition window estimate based on an overlap between the estimate of (a) and (b); (d) comparing the estimate of (c) to a threshold; (e) repeating (a) through (d) for successive time periods using the fine transition window estimate of (c) as the prior transition window estimate of (b) until the fine transition window estimate of (c) satisfies the threshold; and (f) establishing the fine transition window estimate as an established moment of transition between windows when the estimate of (c) satisfies the threshold.

In some examples, the instructions further cause the machine to identify the moments of transition between time periods of the media signal based on the established moment of transition.

In some examples, the time periods correspond to successive minutes of the media signal and the threshold is about five seconds.

Also disclosed herein are example systems that include means for detecting watermarks and means for decoding timestamps in respective ones of the watermarks. Such example systems also include means for determining moments of transition between time periods of media containing the watermarks based on the timestamps by: (a) estimating a coarse transition window between two time periods; (b) mapping a prior transition window estimate to the estimate of (a); (c) narrowing to a fine transition window estimate based on an overlap between the estimate of (a) and (b); (d) comparing the estimate of (c) to a threshold; (e) repeating (a) through (d) for successive time periods using the fine transition window estimate of (c) as the prior transition window estimate of (b) until the fine transition window estimate of (c) satisfies the threshold; and (f) establishing the fine transition window estimate as an established moment of transition between time periods when the estimate of (c) satisfies the threshold.

In some example systems, the means for determining is to identify the moments of transition between time periods of the media signal based on the established moment of transition.

In some example systems, the time periods correspond to successive minutes of the media signal and the threshold is about five seconds.

These and other example methods, apparatus, systems and articles of manufacture (e.g., physical storage media) to implement improve timestamp transition resolution in watermarks in media are disclosed in greater detail below.

As used herein, the term "media" includes any type of content and/or advertisement delivered via any type of distribution medium. Thus, media includes television programming or advertisements, radio programming or advertisements, movies, web sites, streaming media, etc. Further, media includes audio and/or visual (still or moving) content and/or advertisements.

Example methods, apparatus, and articles of manufacture disclosed herein monitor media presentations at media devices. Such media devices may include, for example, Internet-enabled televisions, personal computers, Internet-enabled mobile handsets (e.g., a smartphone), video game consoles (e.g., Xbox®, PlayStation®), tablet computers (e.g., an iPad®), digital media players (e.g., a Roku® media player, a Slingbox®, etc.), etc. In some examples, media monitoring information is aggregated to determine ownership and/or usage statistics of media devices, relative rankings of usage and/or ownership of media devices, types of uses of media devices (e.g., whether a device is used for browsing the Internet, streaming media from the Internet, etc.), and/or other types of media device information. In examples disclosed herein, monitoring information includes, but is not limited to, media identifying information (e.g., media-identifying metadata, codes, signatures, watermarks, and/or other information that may be used to identify presented media), application usage information (e.g., an identifier of an application, a time and/or duration of use of the application, a rating of the application, etc.), and/or user-identifying information (e.g., demographic information, a user identifier, a panelist identifier, a username, etc.).

Audio watermarking is a technique used to identify media such as television broadcasts, radio broadcasts, advertisements (television and/or radio), downloaded media, streaming media, prepackaged media, etc. Existing audio watermarking techniques identify media by embedding one or more audio codes (e.g., one or more watermarks), such as media identifying information and/or an identifier that may be mapped to media identifying information, into an audio and/or video component. In some examples, the audio or video component is selected to have a signal characteristic sufficient to hide the watermark. As used herein, the terms "code" or "watermark" are used interchangeably and are defined to mean any identification information (e.g., an identifier) that may be inserted or embedded in the audio or video of media (e.g., a program or advertisement) for the purpose of identifying the media or for another purpose such as tuning (e.g., a packet identifying header). To identify watermarked media, the watermark(s) are extracted and used to access a table of reference watermarks that are mapped to media identifying information.

Unlike media monitoring techniques based on codes and/or watermarks included with and/or embedded in the monitored media, fingerprint or signature-based media monitoring techniques generally use one or more inherent characteristics of the monitored media during a monitoring time interval to generate a substantially unique proxy for the media. Such a proxy is referred to as a signature or fingerprint, and can take any form (e.g., a series of digital values, a waveform, etc.) representative of any aspect(s) of the media signal(s) (e.g., the audio and/or video signals forming the media presentation being monitored). A signature may be a series of signatures collected in series over a timer interval. A good signature is repeatable when processing the same media presentation but is unique relative to other (e.g., different) presentations of other (e.g., different) media. Accordingly, the term "fingerprint" and "signature" are used interchangeably herein and are defined herein to mean a proxy for identifying media that is generated from one or more inherent characteristics of the media.

Signature-based media monitoring generally involves determining (e.g., generating and/or collecting) signature(s) representative of a media signal (e.g., an audio signal and/or a video signal) output by a monitored media device and comparing the monitored signature(s) to one or more references signatures corresponding to known (e.g., reference) media sources. Various comparison criteria, such as a cross-correlation value, a Hamming distance, etc., can be evaluated to determine whether a monitored signature matches a particular reference signature. When a match between the monitored signature and one of the reference signatures is found, the monitored media can be identified as corresponding to the particular reference media represented by the reference signature that with matched the monitored signature. Because attributes, such as an identifier of the media, a presentation time, a broadcast channel, etc., are collected for the reference signature, these attributes may then be associated with the monitored media whose monitored signature matched the reference signature. Example systems for identifying media based on codes and/or signatures are long known and were first disclosed in Thomas, U.S. Pat. No. 5,481,294, which is hereby incorporated by reference in its entirety.

As noted above, watermarks can be embedded or otherwise included in media to enable additional information to be conveyed with the media. This information can include timestamps that indicate the time at which a portion of the media signal containing the watermark was broadcast. Timestamps are important for advertisers, for example, to verify the broadcast of their content. Timestamps are also important in media monitoring to identify the moments in time an audience member was exposed to particular media.

The timestamps embedded in watermarks change with the time of day and with a given time resolution. Thus, a timestamp at one minute may be T1 and the next minute may be T2 (e.g., T1 plus one minute). Comparing one watermark to the next would indicate when the time switched from T1 to T2. However, at times the watermarks cannot be detected based on, for example, noise obscuring the media signal. Thus, many watermarks go undetected. When two detected timestamps indicate a change in time from T1 to T2 but there are undetected watermarks in between the two watermarks, the analysis will not indicate precisely when the time changed from T1 to T2. Though timestamps that are encoded in watermarks may be accurate to the second, traditional systems only have a time transition window resolution of one minute. That is, known systems can only estimate a time change in increments of one minute.

Examples disclosed herein improve the time transition window resolution. For example, in a media signal in which the timestamp code is repeated every 4.8 seconds, there are twelve to thirteen opportunities to detect the timestamp per minute. As disclosed herein, the resolution of the time transition window estimate is improved to, for example, about five seconds. As used herein, "about" means +/−0.2 seconds. This improvement provides more accurate estimation of broadcast time and more valuable information. For example, some advertisements are included in broadcast slots or spots of less than a minute including, for example, ten-second, fifteen-second, or thirty-second spots. When the timestamp transition resolution is only precise to a minute, the exact timing of a sub-minute long broadcast cannot be determined accurately based on such known watermarks.

Turning to the figures, a block diagram of an example media monitoring system **100** implementing improved timestamp transition resolution from watermarks in media signals as disclosed herein is illustrated in FIG. **1**. The example media monitoring system **100** of FIG. **1** supports monitoring of media presented at one or more monitored sites, such as an example monitored site **105** illustrated in FIG. **1**. The monitored site **105** includes an example media device **110**, which is also referred to herein as a media presentation device **110**. Although the example of FIG. **1** illustrates one monitored site **105** and one media device **110**, improved timestamp transition resolution from watermarks in media signals as disclosed herein can be implemented in media monitoring systems **100** supporting any number of monitored sites **105** having any number of media devices **110**.

The media monitoring system **100** of the illustrated example includes an example media device meter **125** (also referred to as a meter **125**, a site meter **125**, a site unit **125**, a home unit **125**, a portable device **125**, etc.) to monitor media presented by the media device **110**. In the illustrated example, the media monitored by the media device meter **125** can correspond to any type of media presentable by the media device **110**. For example, monitored media can correspond to media content, such a television programs, radio programs, movies, Internet video, video-on-demand, etc., as well as commercials, advertisements, etc. In the illustrated example, the media device meter **125** determines metering data including timestamps that may identify and/or be used to identify media presented by the media device and the corresponding times (and, thus, infer media exposure) at the monitored site **105**. The media device meter **125** then stores and reports this metering data via an example network **135** to an example data processing facility **140**. The data processing facility **140** performs any appropriate post-processing of the metering data to, for example, determine audience ratings information, identify targeted advertising to be provided to the monitored site **105**, etc. In the illustrated example, the network **135** can correspond to any type(s) and/or number of wired and/or wireless data networks, or any combination thereof.

In the illustrated example, the media device **110** monitored by the media device meter **125** can correspond to any type of audio, video and/or multimedia presentation device capable of presenting media audibly and/or visually. For example, the media device **110** can correspond to a television and/or display device that supports the National Television Standards Committee (NTSC) standard, the Phase Alternating Line (PAL) standard, the Systéme Electronique pour Couleur avec Mémoire (SECAM) standard, a standard developed by the Advanced Television Systems Committee (ATSC), such as high definition television (HDTV), a standard developed by the Digital Video Broadcasting (DVB) Project, etc. As other examples, the media device **110** can correspond to a multimedia computer system, a personal digital assistant, a cellular/mobile smartphone, a radio, a tablet computer, etc.

In the media monitoring system **100** of the illustrated example, the media device meter **125** and the data processing facility **140** cooperate to perform media monitoring based on detected media watermarks. Moreover, the media device meter **125** implements improved timestamp transition resolution as disclosed herein. Examples of watermarks include identification codes, ancillary codes, etc., that may be transmitted within media signals. For example, identification codes can be transmitted as watermarked data embedded or otherwise included with media (e.g., inserted into the audio, video, or metadata stream of media) to uniquely identify broadcasters and/or media (e.g., content or advertisements). Watermarks can additionally or alternatively be used to carry other types of data, such as copyright protection information, secondary data (e.g., such as one or more hyperlinks pointing to secondary media retrievable via the Internet and associated with the primary media carrying the watermark), commands to control one or more devices, etc. Watermarks are typically extracted using a decoding operation.

In the illustrated example of FIG. **1**, the media device meter **125** is implemented by a portable device including an example watermark detector **145** and an example timestamp transition resolution enhancer **150**. In the illustrated example, the watermark detector **145** is configured to detect watermark(s) in media signal(s) output from a monitored media device, such as the example media device **110**. In the illustrated example, the timestamp transition resolution enhancer **150** is configured to improve the timestamp transition resolution of the watermarks detected by the watermark detector **145**. In some examples, the media device meter **125** corresponds to a special purpose portable device constructed to implement the example watermark detector **145** and the example timestamp transition resolution enhancer **150**. In other examples, the media device meter **125** corresponds to any portable device capable of being adapted (via hardware changes, software changes, firmware changes, or any combination thereof) to implement the example watermark detector **145** and the example timestamp transition resolution enhancer **150**. As such, the media device meter **125** can be implemented by a smartphone, a tablet computer, a handheld device, a wrist-watch type device (e.g., a smart watch such as the Apple Watch sold by Apple Inc.), other wearable devices, a special purpose device, etc. In some examples, the media device meter **125** can be implemented by a portable device that, although portable, is intended to be relatively stationary. Furthermore, in some examples, the media device meter **125** can be implemented by, or otherwise included in, the media device **110**, such as when the media device **110** corresponds to a portable device (e.g., a smartphone, a tablet computer, a handheld device, etc.) capable of presenting media. This latter implementation can be especially useful in example scenarios in which a media monitoring application is executed on the media device **110** itself, but the media device **110** prevents, e.g., via digital rights management or other techniques, third-party applications, such as the media monitoring application, from accessing protected media data stored on the media device **110**. An example implementation of the media device meter **125** is illustrated in FIG. **3**, which is described in further detail below. Though described as incorporated with the media device meter **125**, the timestamp transition resolution enhancer **150** may be incorporated additionally or alternatively with the data processing facility **140**. Furthermore, in some examples, the media device meter **125** may additionally collect signatures.

FIG. **2** illustrates an example watermark **200** that the example media device meter **125** may be configured to detect. The watermark **200** of the illustrated is embedded or otherwise included in media to be presented by media device(s), such as the example media device **110**. For example, the watermark **200** may be embedded in an audio portion (e.g., an audio data portion, an audio signal portion, etc.) of the media, a video portion (e.g., a video data portion, a video signal portion, etc.) of the media, or a combination thereof. The example watermark **200** of FIG. **2** includes an example first group of symbols **205** and an example second group of symbols **210**. In the illustrated example of FIG. **2**, the first group of symbols **205** is repeated in successive watermarks **200** embedded/included in the media, whereas the second group of symbols **210**, which is indicative of a broadcast time, differs between successive watermarks **200** embedded/included in the media.

In the example watermark of FIG. **2**, the first group of symbols **205** conveys media identification data (e.g., a media identifier) identifying the media watermarked by the watermark **200**. For example, the media identification data conveyed by the first group of symbols **205** may include data identifying a broadcast station providing the media, a name (e.g., program name) of the media, a source (e.g., a website) of the media, etc. Thus, in the illustrated example of FIG. **2**, the first group of symbols **205** is also referred to as a first group of media identification symbols **205** (or simply the media identification symbols **205**). Furthermore, the media identification data conveyed by the first group of symbols **205** (e.g., the media identification symbols **205**) is repeated in successive watermarks **200** embedded/included in the media.

In some examples, the first group of symbols **205** of the watermark **200** includes example marker symbols **215**A-B to assist the watermark detector **145** in detecting the start of the watermark **200** in the watermarked media, and example data symbols **220**A-F to convey the media identification data. Also, in some examples, corresponding symbols pairs in similar respective locations after the first marker symbol **215**A and the second marker symbol **215**B are related by an offset. For example, the value of data symbol **220**D may correspond to the value of data symbol **220**A incremented by an offset, the value of data symbol **220**E may correspond to the value of data symbol **220**B incremented by the same offset, and the value of data symbol **220**F may correspond to the value of data symbol **220**C incremented by the same offset, as well. In such examples, the symbols pairs **220**A/D, **220**B/E and **220**C/F are referred to as symbol offset pairs, or offset pairs, and the offset used to generate the symbol offset pairs forms an additional data symbol that can be used to convey the media identification data.

In the example watermark **200** of FIG. **2**, the second group of symbols **210** conveys timestamp data (e.g., a timestamp) identifying, for example, a particular elapsed time within the watermarked media. Thus, in the illustrated example of FIG. **2**, the second group of symbols **210** is also referred to as the second group of timestamp symbols **210** (or simply the timestamp symbols **210**). Furthermore, the timestamp data conveyed by the second group of symbols **210** (e.g., the timestamp symbols **210**) differs in successive watermarks **200** embedded/included in the media (e.g., as the elapsed time of the watermarked media increases with each successive watermark **200**).

In the illustrated example of FIG. **2**, the watermark **200** is embedded/included in the desired media at a repetition interval oft seconds (or, in other words, at a repetition rate of 1/t seconds), with the first group of symbols **205** remaining the same in successive watermarks **200**, and the second group of symbols **205** varying in successive watermarks **200** according to the time resolution supported by the symbols **205**. For example, the symbols **205** may support a time resolution of one minute and, thus, will change on one minute boundaries. For example, the repetition interval t may correspond to t=4.8 seconds. As there are twelve symbols in the example watermark **200** (e.g., eight symbols in the first group of symbols **205** and four symbols in the second group of symbols **210**) each watermark symbol in the illustrated example has a duration of 4.8/12=0.4 seconds. However, other values for the repetition interval t may be used in other examples.

In some examples, a watermark symbol included in the watermark **200** is able to take on one of several possible symbol values. For example, if a symbol in the watermark **200** represents four bits of data, then the symbol is able to take on one of sixteen different possible values. For example, each possible symbol value may correspond to a different signal amplitude, a different set of code frequencies, etc. In some such examples, to detect a watermark symbol embedded/included in watermarked media, the example watermark detector **145** processes monitored media data/signals output from the example media device **110** to determine measured values (e.g., signal-to-noise ratio (SNR) values) corresponding to each possible symbol value the symbol may have. The watermark detector **145** then selects the symbol value corresponding to the best (e.g., strongest, largest, etc.) measured value (possibly after averaging across multiple samples of the media data/signal) as the detected symbol value for that particular watermark symbol.

An example implementation of the media device meter **125** (e.g., which may be a portable device) of FIG. **1** is illustrated in FIG. **3**. In the illustrated example of FIG. **3**, the media device meter **125** includes one or more example sensor(s) **305** to detect media data/signal(s) emitted or otherwise output by the example media device **110**. In some examples, the sensor(s) **305** include an audio sensor to monitor audio data/signal(s) output by the media device **110**. Such an audio sensor may be implemented using any type of audio sensor or audio interface, such as a microphone, a transducer, a cable/wire, etc., capable of receiving and processing audio signals (e.g., such as in the form of acoustic and/or electrical signals). Additionally or alternatively, in some examples, the sensor(s) **305** include a video sensor to monitor video data/signal(s) output by the media device **110**. Such a video sensor may be implemented using any type of video sensor or video interface, such as a camera, a light detector, a cable/wire, etc., capable of receiving and processing video signals (e.g., such as in the form of optical images and/or electrical signals).

The example media device meter **125** of FIG. **3** also includes the example watermark detector **145**. In the illustrated example of FIG. **3**, the watermark detector **145** is configured to detect watermarks, such as the example watermark **200** of FIG. **2**, in the media data/signal(s) detected by the example sensor(s) **305**. In some examples, the watermark detector **145** of FIG. **3** is structured to process audio data/signal(s) obtained by the sensor(s) **305** to detect symbols of instances of the watermark **200** that are encoded in one or more frequencies of the sensed audio data/signal(s), or otherwise encoded in the frequency domain of the sensed audio data/signal(s). Examples of encoding watermarks in the frequency domain of an audio signal, and corresponding example watermark detection techniques that may be implemented by the example watermark detector **145**, are described in U.S. Pat. No. 8,359,205, entitled "Methods and Apparatus to Perform Audio Watermarking and Watermark Detection and Extraction," which issued on Jan. 22, 2013, U.S. Pat. No. 8,369,972, entitled "Methods and Apparatus to Perform Audio Watermarking Detection and Extraction," which issued on Feb. 5, 2013, U.S. Publication No. 2010/0223062, entitled "Methods and Apparatus to Perform Audio Watermarking and Watermark Detection and Extraction," which was published on Sep. 2, 2010, U.S. Pat. No. 6,871,180, entitled "Decoding of Information in Audio Signals," which issued on Mar. 22, 2005, U.S. Pat. No. 5,764,763, entitled "Apparatus and Methods for Including Codes in Audio Signals and Decoding," which issued on Jun. 9, 1998, U.S. Pat. No. 5,574,962, entitled "Method and Apparatus for Automatically Identifying a Program Including a Sound Signal," which issued on Nov. 12, 1996, U.S. Pat. No. 5,581,800, entitled "Method and Apparatus for Automatically Identifying a Program Including a Sound Signal," which issued on Dec. 3, 1996, U.S. Pat. No. 5,787,334, entitled "Method and Apparatus for Automatically Identifying a Program Including a Sound Signal," which issued on Jul. 28, 1998, and U.S. Pat. No. 5,450,490, entitled "Apparatus and Methods for Including Codes in Audio Signals and Decoding," which issued on Sep. 12, 1995, all of which are hereby incorporated by reference in their entireties. U.S. Pat. Nos. 8,359,205, 8,369,972, U.S. Publication No. 2010/0223062, U.S. Pat. Nos. 6,871,180, 5,764,763, 5,574,962, 5,581,800, 5,787,334, and 5,450,490 describe example watermarking systems in which a watermark is included in an audio signal by manipulating a set of frequencies of the audio signal.

In some examples, the watermark detector **145** of FIG. **3** is structured to process audio data/signal(s) obtained by the sensor(s) **305** to detect symbols of instances of the watermark **200** that are encoded in one or more time domain characteristics of the sensed audio signal, such as by modulating the amplitude and/or phase of the audio signal in the time domain. Examples of encoding watermarks in the time domain of an audio signal, and corresponding example watermark detection techniques that may be implemented by the example watermark detector **145**, include, but are not limited to, examples in which spread spectrum techniques are used to include a watermark in an audio signal. For example, such a watermark can be encoded in the audio signal by (1) spreading the watermark by modulating the watermark with a pseudo-noise sequence and then (2) combining the spread watermark with the audio signal. Detection of such a watermark involves correlating the audio signal (after being watermarked) with the pseudo-noise sequence, which de-spreads the watermark, thereby permitting the watermark to be detected after the correlation.

FIG. **4** illustrates an example mapping **400** of segments of a media signal over time. The first row represents the media segments **405(01-41)** during which a watermark **200** is broadcast. In the example mapping **400**, each media segment **405** may have, for example, a duration of five seconds. Thus, there are twelve segments in one minute of a media broadcast. In other examples, other media segment durations may be used including, for example, 4.8 seconds and/or any other desired amount. The "X" in the second row represents the watermarks **200** detected by the watermark detector **145**. In this example, the watermark detector **145** detects eighteen watermarks **200**. Some of the media segments **405** are not associated with a detected watermark. In such examples, the signal may have been obscured by, for example, noise, and the watermark detector **145** may not have been able to detect an associated watermark.

As shown in FIG. **3**, the example media device meter **125** also includes an example timestamp decoder **310**. The timestamp decoder **310** reads the timestamp symbols **210** from the watermark **200** detected by the watermark detector **145**. The time indicated by the timestamp symbols **210** is associated with the media broadcast with which the detected watermark **200** is broadcast. In the example mapping **400** of FIG. **4**, the timestamp decoder **310** having read the timestamps in the watermarks **200**, determines that the time is T−1 in the second detected watermark **200** of the third media segment **405(03)**. In the third detected watermark **200** of the seventh media segment **405(07)**, the timestamp is T. The timestamp reads as time T until the timestamp decoder **310** determines the time is T+1 at the seventh detected watermark **200** of the eighteenth media segment **405(18)**. The detection and decoding process continues throughout operation of the media device meter **125**. In the example shown, a time change to T+2 is detected at the thirteenth detected watermark **200** of the thirty-first media segment **405(31)**, and a time change to T+3 is detected at the seventeenth detected watermark **200** of the fortieth media segment **405(40)**.

With the information available from the watermark detector **145** and the timestamp decoder **310**, the media device meter **125** and/or data processing facility **400** can determine estimated transition windows or coarse transitions windows indicative of when the time of the media broadcast for the associated media segment **405** advanced to the next time unit (e.g., next minute of the day). For example, the media device includes the timestamp transition resolution enhancer **150** which has an example transition window estimator **315**. The transition window estimator **315** determines the estimated transition window based on a difference between two detected watermarks. As shown in FIG. **4**, the time of the media broadcast is T−1 for the third media segment **405(03)**. At the seventh media segment **405(07)**, the detected watermark **200** indicates that the time of the broadcast is T. Thus, the time changed from T−1 to T in between the broadcast of the third media segment **405(03)** and the seventh media segment **405(07)**. As shown in FIG. **4**, there are several media segments **405(04-06)** between the media segments **405** associated with the different watermarks **200**. In this example, these three media segments **405(04-06)** lack detected watermarks due to, for example, obfuscations from noise. Thus, it is not known when exactly the time period switched between T−1 and T. This could have occurred immediately after the third media segment **405(03)** was broadcast up until the seventh media segment **405(07)** was broadcast. Thus, there is a window of time during which the time transition occurred. In this example, the transition window estimator **315** determines a first estimated transition window **410** between time T−1 and T.

The example timestamp transition resolution enhancer **150** also includes an example resolution comparator **320**. The resolution comparator **320** compares the duration of a transition window to a threshold to determine if the duration of the transition window meets the threshold. The threshold establishes the desired resolution of the timestamp transition. In the example where the media segments **405** of FIG. **4** have a five second duration, the first estimated transition window **410** is shown as twenty seconds. That is, the time switched from T−1 to T sometime during those twenty seconds. The resolution comparator **320** compares the time period of twenty seconds to a threshold which may be set, for example, at five seconds. That is, in this example, a timestamp transition resolution of five seconds is desired. In other examples, the threshold is any desirable level of resolution. In this example, the twenty second duration of the first estimated transition window **410** does not meet the threshold of five seconds. Thus, the timestamp transition resolution enhancer **150** continues operation to improve the resolution of the time transition window. If the first estimated transition window **410** does meet the threshold, the timestamp transition resolution enhancer **150** sets the first estimated transition window **410** as the established time transition or the baseline moment of transition.

During continued operation, the example transition window estimator **315** determines subsequent time transitions and the corresponding transition windows. In the illustrated example, the example transition window estimator **315** determines a second estimated transition window **415** between the detection of time T at the sixth detected watermark **200** of the thirteenth media segment **405(13)** and time T+1 at the seventh detected watermark **200** of the eighteenth media segment **405(18)**. In this example, the second estimated transition window **415** is twenty-five seconds long, which is longer in duration than the first estimated transition window **410** and, therefore, alone does not improve the timestamp transition resolution.

The timestamp transition resolution enhancer **150** also includes an example mapper **325** that aligns or maps a reference transition window with an estimated transition window. For example, when the resolution comparator **320** determines that an estimated transition window does not meet the threshold, the mapper **320** uses the estimated transition window as a reference transition window and maps or aligns the reference transition window with a subsequent estimated transition window. A first estimated transition window can be used to predict subsequent estimated transition windows because the transitions between time periods is cyclical. A second estimated transition window and the first estimated transition window (used as a reference transition window) can be used to refine or improve the estimate of the timestamp transition.

In the example of FIG. **4**, the first estimated transition window **410** has a duration of twenty seconds. When the media segments **405** are of a five second duration, there are twelve segments in a minute. Thus, the first transition window **410** would indicate subsequent transition windows every minute or twelve media segments **405**. Thus, in this example, the first transition window **410** is used by the mapper **325** to predict, or estimate, a first reference transition window **420** by mapping the first estimated transition window **410** down twelve media segments **405** to form the first reference transition window **420** in alignment with the second estimated transition window **415**. More specifically, in the example mapping **400** of FIG. **4**, the first estimated transition window **410** appears between the third and sixth media segments **405(03-06)**. When the first estimated transition window **410** is mapped down (in this example one minute), the next estimate for a window transition or the first reference transition window **420** appears twelve media segments later or the fifteenth media segment **405(15)** to the eighteenth media segment **405(18)**.

Based on the second estimated transition window **415**, the timestamp transition resolution enhancer **150** can determine that a change in the time period occurred between the watermark **200** detected in the thirteenth media segment **405(13)** and the watermark **200** detected in the seventeenth media segment **405(17)**. However, the mapping of the first estimated transition window **410** as the first reference transition window **420** shows that the change in the time period occurred during one of the fifteenth to eighteenth media segments **405(15-18)**. With these two estimates, the mapper **325** determines that the change in the time period between T and T+1 occurred during the intersection of these two windows, namely, during the media segments **405(15-17)** that overlap, or intersect, between the second estimated transition window **415** and the first reference transition window **420**, which forms a first mapped transition window **425**. Compared to the coarser first estimated transition window **410** and second estimated transition window, the first mapped transition window **425** represents a fine transition window in which the transition resolution has been improved.

The resolution comparator **320** compares the first mapped transition window **425** to the threshold. If the first mapped transition window meets the threshold, the timestamp transition resolution enhancer **150** sets the first mapped transition window **425** as the established time transition or the baseline moment of transition. In the example of FIG. **4**, the first mapped transition window **425** has a duration of fifteen seconds and fails to meet the threshold of five seconds.

If a desired level of resolution is not met, the timestamp transition resolution enhancer **150** continues operation to improve the resolution of the time transition window, which includes repetition of one or more of the operations identified above. For example, in the illustrated example, the example transition window estimator **315** determines a third estimated transition window **430** between the detection of time T+1 at the twenty-sixth media segment **405(26)** and time T+2 at the thirty-first media segment **405(31)**. In this example, the third estimated transition window **430** is twenty-five seconds long, which is longer in duration than the first mapped transition window **425** and, therefore, alone does not improve the timestamp transition resolution.

The mapper **325** uses the first mapped transition window **425**, to predict, or estimate, a second reference transition window **435** and aligns or maps the second reference transition window **435** with the third estimated transition window **430**. In this example, the first mapped transition window **425** occurs during the fifteenth, sixteenth, or seventeenth media segments **405(15-17)**. When mapped over an additional time period (e.g., a minute) as the second reference transition window **435**, the duration for a subsequent timestamp transition is during the twenty-seventh, twenty-eight, or twenty-ninth media segment **405(27-29)**.

Based on the third estimated transition window **415**, the timestamp transition resolution enhancer **150** can determine that a change in the time period occurred between the twenty-sixth and thirtieth media segments **405(26-30)**. However, the mapping of the first mapped transition window **425** as the second reference transition window **435** shows that the change in the time period occurred during the twenty-seventh, twenty-eight, or twenty-ninth media segment **405 (27-29)**. With these two estimates, the mapper **325** determines that the change in the time period between T+1 and T+2 occurred during the media segments **405** that overlap between the third estimated transition window **430** and the second reference transition window **435**, which forms the second mapped transition window **440**.

The resolution comparator **320** compares the second mapped transition window **440** to the threshold. If the second mapped transition window **440** meets the threshold, the timestamp transition resolution enhancer **150** sets the second mapped transition window **440** as the established time transition or the baseline moment of transition. In the example of FIG. **4**, because the first mapped transition window **435** is wholly overlapped by the third estimated transition window **430**, there is no further improvement to the transition window resolution. Specifically, in this example, the transition window remains fifteen seconds and fails to meet the threshold of five seconds.

As noted above, when a desired level of resolution is not met, the timestamp transition resolution enhancer **150** continues operation to improve the resolution of the time transition window. For example, in the illustrated example, the example transition window estimator **315** determines a fourth estimated transition window **445** between the detection of time T+2 at the thirty-first media segment **405(31)** and time T+3 at the fortieth media segment **405(40)**. In this example, the fourth estimated transition window **445** is fifteen seconds long, which is not shorter in duration than the second mapped transition window **440** and, therefore, alone does not improve the timestamp transition resolution.

The mapper **325** uses the second mapped transition window **440** to predict, or estimate, a third reference transition window **450** and aligns or maps the second reference transition window **450** with the fourth estimated transition window **445**. In this example, the second mapped transition window **440** occurs during the twenty-seventh, twenty-eight, or twenty-ninth media segment **405(27-29)**. When mapped over an additional time period (e.g., a minute) as the third reference transition window **450**, the duration of the subsequent timestamp transition is during the thirty-ninth, fortieth, and forty-first media segments **405(39-41)**.

Based on the fourth estimated transition window **445**, the timestamp transition resolution enhancer **150** can determine that a change in the time period occurred between the thirty-seventh and thirty-ninth media segments **405(37-39)**. However, the mapping of the second mapped transition window **440** as the third reference transition window **450** shows that the change in the time period occurred during the thirty-ninth, fortieth, and forty-first media segments **405(39-41)**. With these two estimates, the mapper **325** determines that the change in the time period between T+2 and T+3 occurred during the media segment **405** that overlaps, or intersects, between the fourth estimated transition window **445** and the third reference transition window **450**, which forms the third mapped transition window **455**. In this example, the third mapped transition window **455** is the thirty-ninth media segment **405(39)**.

The resolution comparator **320** compares the third mapped transition window **455** to the threshold. If the third mapped transition window **455** does not meet the threshold, the timestamp transition resolution enhancer continues through these operations to continue to improve the resolution. If the third mapped transition window **455** meets the threshold, the timestamp transition resolution enhancer **150** sets the third mapped transition window **455** as the established time transition or the baseline moment of transition **460**. In the example of FIG. **4**, the third mapped transition window **450** has a duration of five seconds and meets the threshold.

When a moment of time transition that meets the threshold is achieved, the established time transition **460** is determined. The established time transition **460** is stored in a database **330** in the media device meter **125**, for example. The database **330** may be used for storage and retrieval of some or all data disclosed herein including, for example, data from the sensor(s) **305**, the watermarks **200**, the estimated transition windows **410**, **415**, **430**, **445**, the reference transition windows **420**, **435**, **450**, and the mapped transition windows **425**, **440**, **455**.

When the established time transition **460** is determined, the timestamp transition resolution enhancer **150** retroactively maps prior time transitions in the media signal and/or proactively maps subsequent transitions in the media signal based on the established time transition **460**. For example, in the mapping **400** of FIG. **4**, the established time transition **460** is set at the thirty-ninth media segment **405(39)**. Thus, the transition between time period T+2 and time period T+3 occurred during the thirty-ninth media segment **405(39)**. One unit of the time measurement divided into the media segments can be used to accurately locate the prior time transition, i.e., the transition between time period T+1 and T+2. In the example of FIG. **4**, where the unit of time measurement is one minute and there are five second segments, the timestamp transition resolution enhancer **150** counts back twelve segments and determines that the established transition **460** between time T+1 and time T+2 occurred during the twenty-seventh media segment **405(27)**. Similarly, the timestamp transition resolution enhancer **150** determines that the established time transition **460** between time T and time T+1 occurred during the fifteenth media segment **405(15)**, and the established time transition **460** between time T−1 and time T occurred during the third media segment **405(03)**.

In some examples, the timestamp transition resolution enhancer **150** implements a voting scheme to assess the value of data. In this example, the timestamp transition resolution enhancer **150** discards data indicative of errors. For example, data showing a decrease in a time value, data between watermarks of consecutive media segments showing a missed time unit (e.g., a skipped minute), and other erroneous or questionable data can be ignored.

While an example manner of implementing the media device meter **125** of FIG. **1** is illustrated in FIG. **3**, one or more of the elements, processes and/or devices illustrated in FIG. **3** may be combined, divided, re-arranged, omitted, eliminated and/or implemented in any other way. Further, the example watermark detector **145**, the example timestamp transition resolution enhancer **150**, the example sensor(s) **305**, the example timestamp decoder **310**, the example transition window estimator **315**, the example resolution comparator **320**, the example mapper **325**, the example databased **330**, and/or, more generally, the example media device meter **125** of FIG. **3** may be implemented by hardware, software, firmware and/or any combination of hardware, software and/or firmware. Thus, for example, any of the example watermark detector **145**, the example timestamp transition resolution enhancer **150**, the example sensor(s) **305**, the example timestamp decoder **310**, the example transition window estimator **315**, the example resolution comparator **320**, the example mapper **325**, the example databased **330**, and/or, more generally, the example media device meter **125** could be implemented by one or more analog or digital circuit(s), logic circuits, programmable processor(s), application specific integrated circuit(s) (ASIC(s)), programmable logic device(s) (PLD(s)) and/or field programmable logic device(s) (FPLD(s)). When reading any of the apparatus or system claims of this patent to cover a purely software and/or firmware implementation, at least one of the example, watermark detector **145**, the example timestamp transition resolution enhancer **150**, the example sensor(s) **305**, the example timestamp decoder **310**, the example transition window estimator **315**, the example resolution comparator **320**, the example mapper **325**, the example databased **330**, and/or the example media device meter **125** is/are hereby expressly defined to include a non-transitory computer readable storage device or storage disk such as a memory, a digital versatile disk (DVD), a compact disk (CD), a Blu-ray disk, etc. including the software and/or firmware. Further still, the example media device meter **125** of FIG. **3** may include one or more elements, processes and/or devices in addition to, or instead of, those illustrated in FIG. **3**, and/or may include more than one of any or all of the illustrated elements, processes and devices.

A flowchart representative of example machine readable instructions for implementing the media device meter **125** of FIG. **3** is shown in FIG. **5**. In this example, the machine readable instructions comprise a program for execution by a processor such as the processor **1012** shown in the example processor platform **1000** discussed below in connection with FIG. **6**. The program may be embodied in software stored on a non-transitory computer readable storage medium such as a CD-ROM, a floppy disk, a hard drive, a digital versatile disk (DVD), a Blu-ray disk, or a memory associated with the processor **1012**, but the entire program and/or parts thereof could alternatively be executed by a device other than the processor **1012** and/or embodied in firmware or dedicated hardware. Further, although the example program is described with reference to the flowchart illustrated in FIG. **5**, many other methods of implementing the example media device meter **125** may alternatively be used. For example, the order of execution of the blocks may be changed, and/or some of the blocks described may be changed, eliminated, or combined. Additionally or alternatively, any or all of the blocks may be implemented by one or more hardware circuits (e.g., discrete and/or integrated analog and/or digital circuitry, a Field Programmable Gate Array (FPGA), an Application Specific Integrated circuit (ASIC), a comparator, an operational-amplifier (op-amp), a logic circuit, etc.) structured to perform the corresponding operation without executing software or firmware.

As mentioned above, the example processes of FIG. **5** may be implemented using coded instructions (e.g., computer and/or machine readable instructions) stored on a non-transitory computer and/or machine readable medium such as a hard disk drive, a flash memory, a read-only memory, a compact disk, a digital versatile disk, a cache, a random-access memory and/or any other storage device or storage disk in which information is stored for any duration (e.g., for extended time periods, permanently, for brief instances, for temporarily buffering, and/or for caching of the information). As used herein, the term non-transitory computer readable medium is expressly defined to include any type of computer readable storage device and/or storage disk and to exclude propagating signals and to exclude transmission media. “Including” and “comprising” (and all forms and tenses thereof) are used herein to be open ended terms. Thus, whenever a claim lists anything following any form of “include” or “comprise” (e.g., comprises, includes, comprising, including, etc.), it is to be understood that additional elements, terms, etc. may be present without falling outside the scope of the corresponding claim. As used herein, when the phrase “at least” is used as the transition term in a preamble of a claim, it is open-ended in the same manner as the term “comprising” and “including” are open ended.

The example machine readable instructions **500** of FIG. **5** begin at block **505** when the watermark detector **145** detects one or more watermarks **200** from a media signal. The example timestamp decoder **310** decodes a timestamp (Tn) from the watermarks (block **510**) (in some examples n is initially set at 0). For example, the timestamp decoder **310** reads timestamps such as timestamp symbols **210** from the watermark **200**. The example timestamp decoder **310** analyzes a media signal to detect and monitor subsequent watermarks and timestamps (block **515**). The example timestamp transition resolution enhancer **150** determines if a watermark includes a timestamp indicative of a change in time (Tn+1) (block **520**). For example, the watermark **200** includes time symbols **210** that indicate the time at which the watermark **200** and associated media content was broadcast. As the time of day progresses, the time symbols **210** change. Eventually, a subsequent watermark **200** will include a timestamp that indicates a change of time from (Tn) to (Tn+1).

If a watermark **200** does not include a timestamp indicative of a change in time (block **520**), the example timestamp decoder **310** continues to detect and decode watermarks and timestamps (block **515**). However, if a watermark **200** does include a timestamp indicative of change in time (block **520**), the example transition window estimator **315** of the example timestamp transition resolution enhancer **150** identifies an estimated transition window (Wn) (block **525**). For example, the transition window estimator **315** determines a duration of time or time window during which the time changed from one time period to a second time period based on the duration between the two watermarks with disparate timestamps. As disclosed in the example above, the transition window estimator **315** determines the first estimated transition window **410**.

The example resolution comparator **320** of the example timestamp transition resolution enhancer **150** determines if the estimated transition window (Wn) meets or satisfies a threshold time duration (block **530**). In some examples, the threshold is set at five seconds, though other values may be used. If the estimated transition window (Wn) is five seconds or less, in this example, the resolution comparator **320** will determine that the threshold is met. In other words, the desired resolution of estimating when a time transition occurred has been satisfied. When the estimated transition window (Wn) is determined to meet the threshold (block **530**), the example timestamp transition resolution enhancer **150** continues and sets the estimated transition window (Wn) as the moment of time transition (block **535**).

When the moment of time transition is set (block **535**), the example timestamp transition resolution enhancer **150** retroactively and/or proactively sets prior and/or subsequent moments of time transitions (block **540**). For example, the timestamp transition resolution enhancer **150** sets the established moment of time transition **460** when the resolution threshold is met. Once a moment of time transition is established with the desired resolution, other moments of time transition can be determined based on the number of media segments in a time unit. In the example disclosed above, there are five second media segments and, therefore, twelve segments in a minute. When the threshold of five seconds (e.g., one media segment) is met, the timestamp transition resolution enhancer **150** sets the moment of time transition **460** and can count forward and/or backward twelve media segments to mark or otherwise note moments of other time transitions. When the moments of time transition are marked to the desired resolution level, the example program **500** ends.

When the estimated transition window (Wn) does not meet the threshold time duration (block **530**), the example timestamp transition resolution enhancer **150** continues and sets the estimated transition window (Wn) as a reference transition window (block **545**). For example, the timestamp transition resolution enhancer **150** sets the first estimated transition window **410** as the first referenced transition window **420** when the first estimated transition window **410** fails to meet the threshold.

The example timestamp decoder **310** and the example timestamp transition resolution enhancer **150** continue and analyze the media signal to detect and monitor subsequent watermarks and timestamps (block **550**) to detect a watermark including a timestamp indicative of a change in time (Tn+2) (block **555**). If a watermark **200** does not include a timestamp indicative of a change in time (block **555**), the example timestamp transition resolution enhancer **150** continues to detect and decode watermarks and timestamps (block **550**). However, if a watermark **200** does include a timestamp indicative of change in time (block **555**), the example timestamp transition resolution enhancer **150** identifies an estimated transition window (Wn+1) (block **560**). For example, the transition window estimator **315** determines a duration of time or time window during which the time changes from a second time period to a third time period based on the duration between the two watermarks with disparate timestamps. As disclosed in the example above, the transition window estimator **315** determines the second estimated transition window **415**.

Though not explicitly shown in FIG. **5**, in some examples, the example timestamp transition resolution enhancer **150** determines if the estimated transition window between the second time period and the third time period meets the threshold similar to block **530**. If the threshold is met, the example program would continue through blocks **535** and **540** as detailed above.

When the estimated transition window (Wn+1) is determined (block **560**), and the estimated transition window (Wn+1) fails to meet the threshold or is not compared to the threshold, the example mapper **325** of the example timestamp transition resolution enhancer **150** maps or aligns the reference transition window (Wn) with the estimated transition window (Wn+1) (block **565**). For example, the mapper **325** maps the first estimated transition window **410** as the first reference transition window **420** to the second estimated transition window **415**. The example timestamp transition resolution enhancer **150** determines an overlap between the reference transition window (Wn) and the estimated transition window (Wn+1) (block **570**). For example, the timestamp transition resolution enhancer **150** determines what media segments **405(15-17)** overlap between the media segments **405(15-18)** broadcast during the duration of the first reference transition window **420** and the media segments **405(13-17)** broadcast during the duration of the second estimated transition window **415**. The example timestamp transition resolution enhancer **150** sets the overlap as the mapped transition window (block **575**). In the example disclosed above, the timestamp transition resolution enhancer **150** sets the overlap between the second estimated transition window **415** and the first reference transition window **420** as the first mapped transition window **425**. In another example, the timestamp transition resolution enhancer **150** sets the overlap between the fourth estimated transition window **445** and the third reference transition window **450** as the third mapped transition window **455**.

The example resolution comparator **320** of the example timestamp transition resolution enhancer **150** determines if the mapped transition window meets a threshold time duration (block **580**). In some examples, the threshold is set at five seconds, though other values may be used. If the mapped transition window is five seconds or less, in this example, the resolution comparator **320** will determine that the threshold is met. In other words, the desired resolution of estimating when a time transition occurred has been satisfied. When the mapped transition window is determined to meet the threshold (block **580**), the example timestamp transition resolution enhancer **150** continues and sets the mapped transition window as the moment of time transition (block **585**). In one of the examples disclosed above, the resolution comparator **320** determines that the third mapped transition window **455** meets the threshold of five seconds. The timestamp transition resolution enhancer **150** sets the third mapped transition window **455** as the established time transition **460**.

When the moment of time transition is set (block **585**), the example timestamp transition resolution enhancer **150** retroactively and/or proactively sets prior and/or subsequent moments of time transitions (block **540**), as disclosed above. For example, the timestamp transition resolution enhancer **150** sets the established moment of time transitions **460** when the resolution threshold is met for other time transitions during the broadcast of the media signal. When the moments of time transition are marked to the desired resolution level, the example program **500** ends.

If the mapped transition window fails to the meet the threshold time duration (block **580**), the example timestamp transition resolution enhancer **150** sets the mapped transition window as the reference transition window (Wn) (block **590**). For example, when the first mapped transition window **425** fails to meet the threshold of five seconds, the timestamp transition resolution enhancer **150** sets the first mapped transition window **425** as the second reference transition window **435**. Thereafter, the example timestamp decoder **310** and the example timestamp transition resolution enhancer **150** continue to monitor the media signal and repeating the analysis by returning to block **550**, after incrementing n (block **595**) to indicate the subsequent time periods being analyzed.

The example timestamp decoder **310** and the example timestamp transition resolution enhancer **150** continue execution until it is determined that the duration of the mapped transition window satisfies the threshold setting the desired resolution of a time transition window (block **580**). When the threshold is satisfied, or the desired resolution is otherwise determined to be met, the example timestamp transition resolution enhancer **150** proceeds through setting the mapped transition window as the moment of time transition (block **585**) and mapping prior and/or subsequent time transition (block **540**) as disclosed above until the example program **500** ends.

FIG. **6** is a block diagram of an example processor platform **600** structured to execute the instructions of FIG. **5** to implement the media device meter **125** of FIG. **3**. The processor platform **600** can be, for example, a server, a personal computer, a mobile device (e.g., a cell phone, a smart phone, a tablet such as an iPad™), a personal digital assistant (PDA), an Internet appliance, a DVD player, a CD player, a digital video recorder, a Blu-ray player, a gaming console, a personal video recorder, a set top box, or any other type of computing device.

The processor platform **600** of the illustrated example includes a processor **605**. The processor **605** of the illustrated example is hardware. For example, the processor **605** can be implemented by one or more integrated circuits, logic circuits, microprocessors or controllers from any desired family or manufacturer. The hardware processor may be a semiconductor based (e.g., silicon based) device. In this example, the processor **605** implements the example watermark detector **145**, the example timestamp transition resolution enhancer **150**, the example timestamp decoder **310**, the example transition window estimator **315**, the example resolution comparator **320**, and the example mapper **325**.

The processor **605** of the illustrated example includes a local memory **610** (e.g., a cache). The processor **605** of the illustrated example is in communication with a main memory including a volatile memory **615** and a non-volatile memory **620** via a bus **625**. The volatile memory **615** may be implemented by Synchronous Dynamic Random Access Memory (SDRAM), Dynamic Random Access Memory (DRAM), RAMBUS Dynamic Random Access Memory (RDRAM) and/or any other type of random access memory device. The non-volatile memory **620** may be implemented by flash memory and/or any other desired type of memory device. Access to the main memory **615**, **620** is controlled by a memory controller.

The processor platform **600** of the illustrated example also includes an interface circuit **630**. The interface circuit **630** may be implemented by any type of interface standard, such as an Ethernet interface, a universal serial bus (USB), and/or a PCI express interface.

In the illustrated example, one or more input devices **635** are connected to the interface circuit **630**. The input device(s) **635** permit(s) a user to enter data and/or commands into the processor **605**. The input device(s) can be implemented by, for example, an audio sensor, a microphone, a camera (still or video), a keyboard, a button, a mouse, a touchscreen, a track-pad, a trackball, isopoint and/or a voice recognition system.

One or more output devices **640** are also connected to the interface circuit **630** of the illustrated example. The output devices **640** can be implemented, for example, by display devices (e.g., a light emitting diode (LED), an organic light emitting diode (OLED), a liquid crystal display, a cathode ray tube display (CRT), a touchscreen, a tactile output device, a printer and/or speakers). The interface circuit **630** of the illustrated example, thus, typically includes a graphics driver card, a graphics driver chip and/or a graphics driver processor.

The interface circuit **630** of the illustrated example also includes a communication device such as a transmitter, a receiver, a transceiver, a modem and/or network interface card to facilitate exchange of data with external machines (e.g., computing devices of any kind) via a network **645** (e.g., an Ethernet connection, a digital subscriber line (DSL), a telephone line, coaxial cable, a cellular telephone system, etc.).

The processor platform **600** of the illustrated example also includes one or more mass storage devices **650** for storing software and/or data. Examples of such mass storage devices **650** include floppy disk drives, hard drive disks, compact disk drives, Blu-ray disk drives, RAID systems, and digital versatile disk (DVD) drives.

The coded instructions **655** of FIG. **5** may be stored in the mass storage device **655**, in the volatile memory **615**, in the non-volatile memory **620**, and/or on a removable tangible computer readable storage medium such as a CD or DVD.

From the foregoing, it will be appreciated that example methods, apparatus and articles of manufacture have been disclosed that improve or enhance the resolution of a timestamp transition window. Media signals contain watermarks with timestamps indicative of the time of broadcast of the portion of the media signal associated with the watermark. Media content providers and advertisers want to know precisely when their media was broadcast, and the timestamps in the watermarks are used to provide this information.

In some prior watermarking solutions, the exact broadcast time of media broadcast in time slots smaller than the transition window will go undetected. For example, a transition window of one minute will not identify exactly when an advertisement with a duration of twenty seconds was broadcast. An advertiser who paid for a twenty second advertisement spot at the beginning of a minute-long advertisement break would want to know that their advertisement was in fact broadcast during the first twenty seconds of the advertisement break. This level of precision cannot be provided when the timestamp transition window is too large. Examples disclosed herein improve the timestamp transition resolution to overcome the limitation of the prior art. In some examples, the resolution is improved to five seconds. The improved resolution enables the exact broadcast times of each moment of the media signal to be pinpointed down to the resolution threshold (e.g., 5 seconds). This improvement has been developed and is usable without requiring the broadcast of additional watermarks, enhanced detection techniques to capture more watermarks, or a more finite segmentation of media signals.

Although certain example methods, apparatus and articles of manufacture have been disclosed herein, the scope of coverage of this patent is not limited thereto. On the contrary, this patent covers all methods, apparatus and articles of manufacture fairly falling within the scope of the claims of this patent.

What is claimed is:

1. An apparatus comprising:

at least one memory;

instructions on the apparatus; and

at least one processor to execute the instructions to at least:

(a) estimate, based on timestamps decoded from respective watermarks detected in media, a coarse transition window between two time periods of the media;

(b) map a prior transition window estimate to the estimate of (a);

(c) determine a fine transition window estimate based on an overlap between the estimate of (a) and (b);

(d) compare the fine transition window estimate of (c) to a threshold;

(e) repeat (a) through (d) for successive time periods of the media using the fine transition window estimate of (c) as the prior transition window estimate of (b) until the fine transition window estimate of (c) satisfies the threshold; and

(f) set the fine transition window estimate to be an established moment of transition between time periods of the media when the estimate of (c) satisfies the threshold.

2. The apparatus of claim **1**, wherein the threshold is one time unit.

3. The apparatus of claim **1**, wherein the at least one processor is to identify a plurality of moments of transition between the time periods of the media based on the established moment of transition.

4. The apparatus of claim **1**, wherein the time periods correspond to successive minutes of the media and the threshold is about five seconds.

5. The apparatus of claim **1**, wherein the at least one processor is to estimate the coarse transition window when a first timestamp from a first watermark is different than a second timestamp from a second watermark.

6. The apparatus of claim **1**, wherein the at least one processor is to map the established moment of transition forward in the media by multiples of a number of time units to determine one or more additional established moments of transition.

7. The apparatus of claim **1**, wherein the at least one processor is to map the established moment of transition backward in the media by multiples of a number of time units to determine one or more additional established moments of transition.

8. A system comprising:
means for detecting watermarks in media;
means for decoding timestamps from respective ones of the watermarks; and
means for determining an established time transition, the means for determining to:
identify a first transition window between a first watermark detected in the media and a second watermark detected in the media;
calculate a first number of time units between the first watermark and the second watermark;
when the first number of time units is greater than a threshold,
set the first transition window as a first reference transition window, and
map the first reference transition window forward by a second number of time units;
identify a second transition window between the second watermark and a third watermark detected in the media;
calculate a third number of time units between the second watermark and the third watermark;
when the third number of time units is greater than the threshold, calculate a fourth number of time units included in an overlap between the first reference transition window and the second transition window; and
when the fourth number of time units is less than or equal to the threshold, set the overlap between the first reference transition window and the second transition window as an established time transition.

9. The system of claim **8**, wherein the threshold is one time unit.

10. The system of claim **8**, wherein the means for determining is to identify a plurality of moments of transition between the watermarks in the media based on the established time transition.

11. The system of claim **8**, wherein the means for determining is to map the established time transition forward in the media by multiples of the second number of time units to determine one or more additional established time transitions.

12. The system of claim **8**, wherein the means for determining is to map the established time transition backward in the media by multiples of the second number of time units to determine one or more additional established time transitions.

13. The system of claim **8**, wherein a time unit is about five seconds.

14. An apparatus comprising:
at least one memory;
instructions on the apparatus; and
at least one processor to execute the instructions to at least:
decode timestamps in respective ones of watermarks detected in a media signal;
estimate a first transition window indicative of a transition between a first time period to a second time period based on a first one of the timestamps and a second one of the timestamps;
when the first transition window does not satisfy a threshold, estimate a second transition window indicative of a transition between the second time period and a third time period based on the second one of the timestamps and a third one of the timestamps;
determine a first mapped transition window based on an intersection of the first transition window and the second transition window; and
set the first mapped transition window as a reference time transition window for subsequent time periods.

15. The apparatus of claim **14**, wherein the at least one processor is to set the first transition window as an established time transition when the first transition window satisfies the threshold.

16. The apparatus of claim **14**, wherein the at least one processor is to set the first mapped transition window as an established time transition when the first mapped transition window satisfies the threshold.

17. The apparatus of claim **14**, wherein the at least one processor is to:
when the first mapped transition window does not satisfy the threshold, estimate a third transition window indicative of a transition between the third time period and a fourth time period of time based on the third one of the timestamps and a fourth one of the timestamps;
determine a second mapped transition window based on an intersection of the first mapped transition window and the third transition window; and
set the second mapped transition window as the reference time transition window.

18. The apparatus of claim **17**, wherein the at least one processor is to set the second mapped transition window as an established time transition when the second mapped transition window satisfies the threshold.

19. The apparatus of claim **14**, wherein the at least one processor is to:
set an established time transition based on at least one of the first transition window or the first mapped transition window satisfying the threshold; and
retroactively map time transitions in the media signal based on the established time transition.

20. The apparatus of claim **14**, wherein respective ones of the time periods have minute durations and the threshold is about five seconds.

21. The apparatus of claim **14**, wherein the first transition window is identified when a first timestamp in a first watermark is different than a second timestamp in a second watermark.

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